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USE OF SALT INDUSTRIES BYPRODUCT AS AN ALTERNATIVE LIQUID FERTILIZER IN FLOATING HYDROPONIC LETTUCE IN BANGLADESH

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ABSTRACT

Salt industries byproduct is a less expensive fertilizer source. But without testing its effect on growth and yield, it may not be suitable as fertilizer. Therefore, a laboratory trial was conducted to evaluate vegetative growth, physiological growth traits and yield of lettuce cv. 'Lolorossa' by application of three salt industries byproduct concentrations at 0 (T_1), 0.5mL.L^{-1} (T_2) and 0.75 mL. L^{-1}(T_3) into ¾ strength Rahman and Inden (2012) nutrient solution. Plant height, number of leaf, leaf length, fresh weight, and physiological growth traits, viz., leaf area (LA), leaf mass ratio (LMR), leaf area ratio (LAR), root weight ratio (RWR),net assimilation rate (NAR) and relative growth rate (RGR) were observed. Results revealed that the maximum number of leaf, leaf breadth and fresh weight were found in salt industries byproduct at 0.5 mL·L^{-1} compared to the control. But the vegetative growth was negatively affected by the application of salt industries byproduct at 0.75mL·L^{-1}. Physiological growth straits were negatively affected with increasing rates of salt industries byproduct. It was further found that RGR, NAR, and their related components improved when 0.5 mL·L^{-1} salt industries byproduct was applied compared to the control in lettuce. It may be concluded that salt industries byproduct can be used as liquid fertilizer source in hydroponic lettuce culture.

KEYWORDS: Salt Industries Byproduct, Soilless Culture, Floating Hydroponics & Lettuce

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Original Article

INTRODUCTION

Effects are on to reducing the production cost of agricultural crops. Salt industries by-product can reduce production cost as it contains many macronutrients, especially calcium (Ca^{2+}), magnesium (Mg^{2+}), and micronutrients. It contains sodium (Na^{+}) that may impose mild salinity, but it also contains some silicon (Si) that may minimize the negative effects of salinity. Bradbury and Ahmad (1990) and Liang *et al*. (1996) reported that Si minimized the adverse effects of salinity. Ca^{2+} plays a key role in plant growth and fruit development and is involved in many biochemical and physiological processes (Saure, 2005).

Lettuce (*Lactuca sativa* L.) is the most popular amongst the salad vegetable crops and it is grown in green houses to produce high-quality, colored during an extended season. The production costs can be reduced by reducing nutrition or using cheaper fertilizer sources. The problem with traditional soilless culture is that it relies on costly chemical fertilizers, but the use of salt industries byproduct may reduce this cost. Plant growth analysis

can be performed to monitor changes in overall plant growth affected by the application of salt industries byproduct. The efficiency of salt industries byproduct can be defined in terms of variation in relative growth rate (RGR) and morphological plant traits were studied, which could be used to simplify RGR. More information is available on the effect of light in tensity (Bruggink, 1987; Bruggink and Heuvelink, 1987)and salinity (Villa-Castorena *et al*., 2003) on RGR and its components. But, there is no information on the relationship between RGR and growth-related traits due to the application of salt industries byproduct.

The antioxidant content of fruits and vegetables is becoming increasingly important for growers who want to satisfy the demand of consumers for products with a high content of health-promoting constituents. An increase in antioxidant content in fresh lettuce can be accomplished by improving crop production practices, e.g. selection of varieties rich in phytochemicals and optimization of plant nutrition and water supply (Lee *et al.*, 1995). Furthermore, salt-industries byproduct, as cheaper fertilizer alternative, may be used for improving the antioxidant content in leaves of lettuce as well as reducing production cost. Therefore, the present work was aimed to evaluate the effect of salt industries byproduct application on yield, physiological growth, and antioxidant content in lettuce.

MATERIALS AND METHODS

Experimental Site

Two repeated experiments were conducted in greenhouses and Central Laboratory at Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207, Bangladesh. The transplanting and final harvesting dates of the first trial (Expt. 1) were 25th January and 7th March 2015, and of the second trial (Expt. 2) were 1st November and 15th December 2015, respectively.

Experimental Material

Lettuce cv.‘Lolorossa’ was used for growing hydroponic system in the Laboratory and greenhouse. Seeds of lettuce were collected from the University of Miyazaki, Japan.

Experimental Environment

The seeds were sown in the media mixture of coco peat, brick broken and rice husk at the ratio of 6:2:2 (v/v) into the 20-mL plastic disposable pots. One-week-old seedlings were transferred in the floating hydroponic system (Figure 1). It was made by cork-sheet of 50-cm × 35-cm. Cork sheet box contained nutrient solution. Air pumps and air-stones were used in the box to maintain oxygen content in the nutrient solution. Twenty-one plastic pots with healthy seedlings were transferred in each box. The salt industries byproduct was applied as treatment at 7 days after transplanting. The crop was cultivated for 42 days. The pH and EC of ≅ 6.0 and ≅ 2.8 – 3.0 dS·m^{-1}, respectively were maintained in the nutrient solution.

Experimental Design

Both the experiments were conducted in a complete randomized design with five replications. Three concentrations of salt industries byproduct (SIB) were considered as treatments, viz., T_1– 0 mL·L^{-1}SIB + ¾ strength Rahmanand Inden (2012) as a standard, T_2 – 0.5mL·L^{-1}SIB + ¾ strength Rahmanand Inden (2012), T_3 – 0.75mL·L^{-1}SIB + ¾ strength Rahmanand Inden (2012). A ¾ strength Rahman and Inden (2012) continued to plants until 15 days of transferred to the hydroponic system. After that treatments were started. The standard nutrient solution was selected

according to the findings of our previous experiments (Rahman et al., 2015) in the same greenhouse and same condition. The composition of salt industries byproduct was given in Table 1.

Data Collection

Data were collected on growth and yield contributing characters, viz, plant height, number of leaves, breadth of leaves, leaf length, fresh weight of plant, dry weight of plant, and physiological parameters, viz., leaf area (LA), leaf area ratio (LAR), leaf mass ratio (LMR), root weight ratio (RWR), relative growth rate (RGR), and net assimilation rate (NAR) for both the experiments. The parameters were measured as described below:

$$\mathrm{LAR} = \frac{\mathrm{LA}}{\mathrm{PDW}} \tag{1}$$

Where, LAR = leaf area ratio, LA = Leaf area (cm^2), PDW = plant dry weight (g).

$$\mathrm{LMR} = \frac{\mathrm{LDW}}{\mathrm{PDW}} \tag{2}$$

Where, LMR = leaf mass ratio, LDW = leaf dry weight (g).

$$\mathrm{RWR} = \frac{\mathrm{RDW}}{\mathrm{PDW}} \tag{3}$$

Where, RWR = root weight ratio, RDW = root dry weight (g).

$$\mathrm{RGR} = \frac{\mathrm{PDW_1} - \mathrm{PDW_0}}{(\mathrm{t_1} - \mathrm{t_0}) \times \mathrm{PDW_0}} \tag{4}$$

Where, t = time. Subscripts 0 and 1 refer to the transplanting and final harvest (days), respectively.

$$\mathrm{NAR} = \frac{\mathrm{RGR}}{\mathrm{LAR}} \tag{5}$$

Statistical analysis of data: Data of the two trials were combined and analyzed by one-way analysis of varience (ANOVA) using SPSS version 19.0 and differences among the means were determined by using Tukey's test at $P \leq 0.05$.

RESULTS AND DISCUSSIONS

Plant Height: Two trials combined data for plant height of lettuce are shown in Table 2. Significant difference in plant height was found among the three concentrations of the salt industries byproduct application (Table 2). The longest plants were found in the control which was similar to that of T_2 and the shortest plant was found in T_3. The finding showed that plant height decreased with the increasing rate of salt industries byproduct. This might be due to the fact that salt industries byproduct contains some extent of Na^+ that might have imposed salinity. Furthermore, plant height was not adversely affected by salt industries byproduct at 0.5 $mL \cdot L^{-1}$. The mechanism for improvement of plant height due to application of salt industries byproduct at 0.5 $mL \cdot L^{-1}$ is not clear, but the positive impact of salt industries byproduct is due to the presence of rather high amounts of Ca^{2+} and Si, which might have contributed to reduce Na^+ absorption sites. Bradbury and Ahmad (1990) and Liang *et al.* (1996) reported that Si minimized the effects of salinity in *Prosopisjuliflora* and barley, respectively. Calcium sulfate counteracted the toxic effect of NaCl, resulting in greater plant height and leaf number of salt treated *Leucaenaleucocephala* plant (Hansen and Munns, 1988). Salt industries byproduct contained a higher amount of Ca^{2+} which may able to counteract the toxic effects of Na^+ when salt industries byproduct applied at the rate of 0.5 $mL \cdot L^{-1}$.

Number of Leaves per Plant*:* Two trials combined data for number of leaves per plant of lettuce are shown in Table 2.Significant difference in number of leaves per plant was found among the three concentrations of the salt industries byproduct application (Table 2). The maximum number of leaves was found in salt industries byproduct at 0.5 mL·L^{-1}which was similar to the control and the minimum was found in T_3. The finding showed that number of leaves per plant decreased with increasing rate of salt industries byproduct. The reason might be same which was discussed in case of plant height. But the interesting finding was the higher number of leaves in salt industries byproduct at 0.5 mL·L^{-1} and it was decreased at 0.75 mL·L^{-1}. This might be due to Ca^{2+} and Si content in salt industries byproduct at 0.5 mL·L^{-1} that can improve growth. But higher amount of salt industries byproduct at 0.75 mL·L^{-1} can impose more salt stress to the plant that can reduce growth.

Leaf Breadth: Two trials combined data for leaf breadth of lettuce are shown in Table 2.Significant difference in leaf breadth was found among the three concentration of the salt industries byproduct application (Table 2). The maximum leaf breadth was found in salt industries byproduct at 0.5 mL·L^{-1}which was similar to the control and the minimum was found in T_3. The finding showed that number of leaves per plant decreased with increasing rate of salt industries byproduct. The reason might be same which was discussed in case of plant height. Andriolo *et al.* (2005) stated that lettuce growth was affected by different strength of salinity in the nutrient solution in lettuce. The present finding was also consisted with the findings of Andriolo *et al*. (2005). But the interesting finding was the higher number of leaves in salt industries byproduct at 0.5 mL·L^{-1} and it was decreased at 0.75 mL·L^{-1}. This might be due to Ca^{2+} and Si content in salt industries byproduct at 0.5 mL·L^{-1} that can improve growth. But higher amount of salt industries byproduct at 0.75 mL·L^{-1} can impose more salt stress to the plant that can reduce growth.

Leaf Length: Two trials combined data for leaf length of lettuce are shown in Table 2 and Figure 2. The leaf length was not affected by treatments (Table 2). However, the maximum leaf length was found in the control which was similar to that of T_2 and the minimum was found in T_3. The finding showed that leaf length decreased with increasing rate of salt industries byproduct.

Fresh Weight: Two trials combined data for fresh weight of lettuce are shown in Table 2 and Figure 2. Marketable quality of lettuce is determined mainly by plant size, which depends on fresh weight. Fresh weight per plant was significantly varied by the concentration of salt industries byproduct application (Table 2 and Figure 3). The highest yield was found at salt industries byproduct when applied at 0.5 mL·L^{-1} and the lowest was found at 0.75 mL·L^{-1}. The finding showed that plant fresh weight decreased with increasing rate of salt industries byproduct. In fact, this might be due to higher number of leaf and leaf bread by application of salt industries byproduct at 0.5 mL·L^{-1}. Andriolo *et al.* (2005) also stated that EC levels above 2.6 dS m^{-1} reduce fresh yield and plant growth in lettuce. In the present experiment, EC level of T_3 was higher than that of 2.6 dS m^{-1} and it reduced fresh weight in lettuce by application of salt industries byproduct at 0.75 mL·L^{-1}. Furthermore, Stamatakis *et al.* (2003) found a positive effect of Si addition to the nutrient solution under saline condition in tomato fruit yield and Alexander and Clough (1998) also observed that marketable yield of pepper increased due to increased Ca^{2+}. Similar result was observed in salt industries byproduct at 0.5 mL·L^{-1}in this study. Because, salt industries byproduct contains Ca^{2+} and Si that might have a positive effect on fresh weight in lettuce.

Plant Dry Weight: Two trials combined data for plant dry weight of lettuce are shown in Table 3. Plant dry weights of lettuce significantly varied by salt industries byproduct rates. The highest dry weights of leaf and root were found in salt industries byproduct at 0.5 mL·L^{-1}compared to the control. Meanwhile, dry weights of plants drastically

decreased at0.75 mL·L^{-1}. This might be due to salt industries byproduct at0.5 mL·L^{-1}containing higher Ca^{2+} compared to the control, which contributed to higher dry weights. On the contrary, salt industries byproduct at0.75 mL·L^{-1}contains the highest amount of Ca^{2+} compared to the other treatments, but it might have salinity stress that caused poor dry weights. Epstein and Bloom (2005) reported that Ca^{2+} increased the root dry weight and calcium content in plant tissues. Bar-Tal *et al.* (2001) found that the shoot and root dry weights decreased with increasing Ca^{2+} in sweet pepper. The present findings consisted with the other findings.

Growth Analysis: Two trials combined data for plant growth analysis of lettuce are shown in Table 4. Growth parameters varied significantly by salt industries byproduct rates. Results revealed that LA, LMR, NAR, and RGR increased at 0.5 mL·L^{-1}salt industries byproduct compared to the control, but these traits drastically reduced at 0.75 mL·L^{-1}salt industries byproduct. On the contrary, LAR was the lowest in salt industries byproduct at 0.5 mL·L^{-1} and decreasing trend of RWR was found with increasing rate of salt industries byproduct. Higher LA is one of the important criteria for producing higher metabolites. Prieto *et al.* (2007) reported that increased LA gave the plants an increased ability to intercept light. We found higher LA, and LMR due to application of salt industries byproduct at 0.5 mL·L^{-1} that may have the ability to produce higher metabolites in lettuce. A decreased LAR was found by Starck (1983) in tomato, which agreed with our findings due to application of salt industries byproduct at 0.5 mL·L^{-1}in lettuce. The plant growth analyses data suggested that salt industries byproduct at 0.5 mL·L^{-1} provided better nutrition to the plants, followed by the control. This was most relevant in higher RGR and NAR due to application of salt industries byproduct at 0.5 mL·L^{-1}. But salt industries byproduct at 0.75 mL·L^{-1} may have mild water stress due to salinity that gave the lower growth in lettuce. RWR suggested that mild stress might have been occurred when salt industries byproduct applied at 0.75 mL·L^{-1}and it may have been responsible for the changes in plant growth affecting the allocation of resources between the root system and the rest of the plant. However, plant growth parameters indicated that application of salt industries byproduct at 0.5 mL·L^{-1} supported a higher level of plant growth.

CONCLUSIONS

It was found that growth, fresh marketable yield and physiological growth traits were affected by different concentrations of salt industries byproduct. The maximum number of leaf, leaf breadth and fresh weight were found in salt industries byproduct at 0.5 mL·L^{-1}.Similarly, RGR, NAR, and their related components also improved when 0.5 mL·L^{-1} salt industries byproduct was applied compared to the control. But all of these traits were lower at 0.75 mL·L^{-1} salt industries byproduct. Therefore, salt industries byproduct can be applied as liquid fertilizer source in hydroponic lettuce production. This hypothesis should be tested by more experiments and other aspect of hydroponic lettuce growth by using salt industries by product addition that will be addressed in our next experiments. The present study indicates that the application of salt industries byproduct has positive and also negative impact on hydroponic lettuce. Results revealed that the maximum number of leaf, leaf breadth and fresh weight were found in salt industries byproduct compared to the control. But the vegetative growth was negatively affected by the application of salt industries byproduct. Meanwhile, physiological growth straits were negatively affected with increasing rates of salt industries byproduct. Results revealed that RGR, NAR, and their related components improved salt industries byproduct was applied compared to the control in lettuce. It can be suggested that salt industries byproduct can be used as liquid fertilizer source in hydroponic lettuce culture in Bangladesh.

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APPENDICES

Table 1: Composition of Salt Industries Byproduct Analyzed by Inductively Coupled Plasma Spectroscopy

Components	P	K	Ca	Mg	S	Fe	Mn	Zn	B	Mo	Na	Si
(ppm)	1860	63081	94658	139669	96854	4133	1471	53	941	454	32525	642

Table 2: Effect of Salt Industries Byproduct on Vegetative Growth and Yield in Lettuce

Treatment	Plant Height (cm)	Number of Leaf per Plant	Leaf Breadth (cm)	Leaf Length (cm)	Yield (g/plant)
T_1	28.09 a	19.00 a	9.22 a	23.01	42.93 b
T_2	24.06 a	20.67 a	12.97 a	20.93	51.33 a
T_3	19.11 b	14.33 b	7.86 b	19.27	36.56 c
P	0.020	0.011	0.001	0.303	0.011
	**	**	**	NS	**

[z]Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. *P* represents the level of significance of one-way ANOVA. NSnonsignificant at $P \leq 0.05$. ** significant$P \leq 0.01$. DAT – Days after transfer.T_1: 0 mL·L^{-1} salt industries byproduct (SIB) + ¾ strength Rahman and Inden (2012), T_2: 0.5mL·L^{-1}SIB + ¾ strength RahmanandInden (2012), T_3: 0.75mL·L^{-1}SIB + ¾ strength Rahmanand Inden (2012).

Table 3: Effect of Salt Industries Byproduct on Plant Dry Weights in Lettuce

Treatment	Plant Dry Weight (g/Plant)	
	Leaf	Root
T_1	1.58 b	0.33 a
T_2	2.35 a	0.37 a
T_3	1.45 b	0.20 b
P	0.012	0.011
	**	**

[z]Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. *P* represents the level of significance of one-way ANOVA. ** significant at $P \leq 0.01$. DAT – Days after transfer.T_1: 0 mL·L^{-1} salt industries byproduct (SIB) + ¾ strength Rahman and Inden (2012), T_2: 0.5 mL·L^{-1}SIB + ¾ strength Rahman and Inden (2012), T_3: 0.75 mL·L^{-1}SIB + ¾ strength Rahman and Inden (2012).

Table 4: Effects of Salt Industries Byproduct on Physiological Growth Traits of Lettuce

Treatment	LA (cm^2)	LMR ($g\ g^{-1}$)	LAR ($cm^2\ g^{-1}$)	RWR ($g\ g^{-1}$)	NAR ($g\ cm^{-2}\ d^{-1}$)	RGR ($g\ g^{-1}\ d^{-1}$)
T_1	145.01 b[z]	0.83 c	75.92 a	0.172 a	0.0000076 b	0.00054 b
T_2	179.45 a	0.88 a	65.97 b	0.136 b	0.0000115 a	0.00077 a
T_3	111.91 c	0.86 b	67.82 b	0.121 c	0.0000069 c	0.00047 c
P	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	**	**	**	**	**	**

[z]Means with different letter is significantly different by Tukey's test at $P \leq 0.05$. *P* represents the level of significance of one-way ANOVA. ** Significant at $P \leq 0.01$. LA = Leaf area; LMR = Leaf mass ratio; LAR = Leaf area ratio; RWR = Root weight ratio; NAR = Net assimilation rate; RGR = Relative growth rate.T_1: 0 mL·L^{-1} salt industries byproduct (SIB) + ¾ strength Rahman and Inden (2012), T_2: 0.5 mL·L^{-1}SIB + ¾ strength Rahman and Inden (2012), T_3: 0.75 mL·L^{-1}SIB + ¾ strength Rahman and Inden (2012).

Figure 1: Lettuce Culture in Hydroponic System at the Starting Time in the Laboratory of Sher-e-Bangla Agricultural University

Figure 2: Lettuce Culture in Hydroponic System at the End of the Experiment